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Comparative Study of Dual Active Bridge Converter for EV Applications with PI and Neuro Fuzzy Control

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***Abstract*—The demand of electric vehicles is booming on account of its advantages like reduced carbon footprint, economy of traveling, almost noise free operation etc. The DC to DC converter is an important element in electric vehicles and many researchers are focusing on development of bidirectional DC to DC converter and their control unit. A dual active bridge converter is a preferred choice for the same on account of its advantages like bidirectional power flow, high power density, easy implementation of zero-voltage switching, convenient access to cascading and parallelism. This paper presents a Neuro fuzzy controlled bidirectional Dual Active Bridge converter for electric vehicle battery management in battery charging (grid to vehicle) and discharging (vehicle to grid). The neuro fuzzy logic controller is developed and MATLAB-Simulink simulation results are presented. The performance of neuro fuzzy controller is compared with PID controller for same dual active bridge converter.**

***Index Terms*— bidirectional DC to DC Converter, Dual Active Bridge, DAB, Battery Charging.**

I. INTRODUCTION

The DC to DC converters are categorized into isolated and non isolated converters. In isolated converters input and output are isolated from each other and have separate grounds. The coupling between the two is done with the help of transformer. Such converters are particularly suited for high voltage gains. By modifying the Transformer ratios voltage gain can be adjusted. These converters typically operate at low duty cycle ratio.

Dual active bridge converter is isolated type bidirectional DC to DC Converter with full bridges on either side. These bridges are driven with square wave pulses of around 50% duty cycle and the power flow is controlled by using phase shift modulation. The bridge with leading phase angle delivers power to the bridge with lagging phase angle. A dual active bridge converter is being preferred on account of its advantages like galvanic isolation between low and high voltage side, adjustable voltage ratio and high efficiency.

II. BIDIRECTIONAL DUAL ACTIVE BRIDGE CONVERTER

A detailed review of DC to DC converters is presented in [1] along with a comparative study indicating advantages, disadvantages, applications and voltage gain. Based on the main classifications, the galvanic isolation is necessary for the high step-up voltage ratio since it offers better utilization for switching device and reducing the circulating reactive power [2]. The power transfer analysis of DAC converter and its operating

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modes through its operating modes controlled by the gate driving waveform [4]. The performance of these converters is characterized by knowing power flow handling, efficiency and accuracy. Among the DC-DC converters 'bi-directional dual active bridge (DAB) DC-DCconverter' is preferred to improve overall efficiency, power flow and for fast response in electric vehicle applications and also in other applications [5].

A dual active bridge converter is controlled by phase shift switching strategy. Here, a DAB converter is connected in series with a bidirectional non-isolated buck boost converter. The single phase shift switching control technique achieves zero voltage switching over entire operating range. It knocks higher efficiency of 97% plus against conventional converter having efficiency near 95% [8]. A dual active bridge DC-DC converter for distributed energy resources and smart grid provides a high level of reliability and resilience to grid disturbances indeed the converter ensured a stable DC bus voltage when the micro grid was operated in islanded mode [10].

The performance of dual active bridge converter is further improved by implementing the converter with high frequency centre tapped transformer and modified phase shift control. The center-tapped inductor at the secondary side can provide the extra soft-switching current for the switches. Such an improved dual active bridge converter is appropriate solution for renewable energy applications subjected to large variations in input voltage. The modified phase shift control scheme works out the less soft-switching current at light load and the too large reactive power at heavy load, which increase the reliability and practicability of the converter [12].

The use of dual active bridge converter simplifies connection of low voltage PV system with high voltage DC bus in renewable energy systems [15]. Even V2G and G2V interface configurations are simplified with DAB converter [16]. DAB converter can find application in battery management of electric vehicles wherein it can manage charging and discharging operation of battery. Researchers have obtained the maximum efficiency of DAB converter to be around 93% [17].

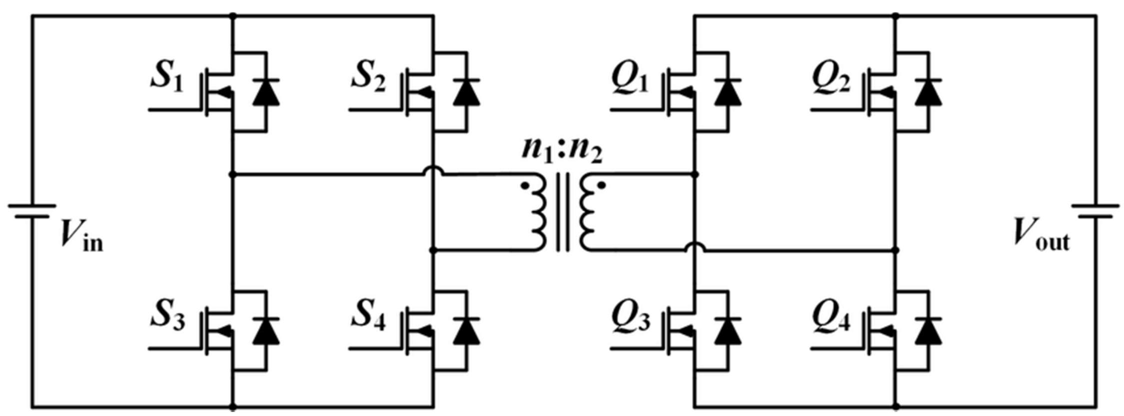

Figure 1: Circuit scheme of dual active bridge converter

A Dual Active Bridge is a DC/DC converter offering galvanic isolation and bidirectional power flow. The galvanic isolation is ensured by a high-frequency intermediary transformer. The topology of the dual active bridge converter is shown in figure 1. A dual active bridge is a bidirectional DC-DC converter with identical primary and secondary side full-bridges, a high frequency transformer, an energy transfer inductor and DC-link capacitors. The two legs of both full-bridges are driven with complimentary square-wave pulses. Power flow in the dual active bridge can be directed by phase- shifting the pulses of one bridge with respect to the other using phase shift modulation. The control directs power between the two DC buses such that the leading bridge delivers power to the lagging bridge. The applied square waves to the bridges create a voltage differential across the energy transfer inductance and direct its stored energy.

III. MATLAB SIMULATIONS AND RESULTS

The MATLAB model of dual active bridge converter is shown in figure 2. The converter is developed for controlling of electric vehicle battery charging and discharging operation. The battery operation control is in two modes namely grid to vehicle (G to V) and vehicle to grid (V to G). In grid to vehicle mode, the charging of battery takes place whereas, in vehicle to grid mode, the power flow is reversed. i.e. from battery to grid thus making the converter bidirectional and suitable of grid interface of the electric vehicle. The converter simulation is done with PI controller and neuro fuzzy controller. The simulation is executed for knowing the status of DC link voltage, power delivery to / from the grid, battery status in terms of state of charge, in two modes according to the power flow. In first mode the power flow is directed from grid to vehicle battery and in the second mode the power flow directedfrom vehicle to grid. The simulation results are subsequently presented.

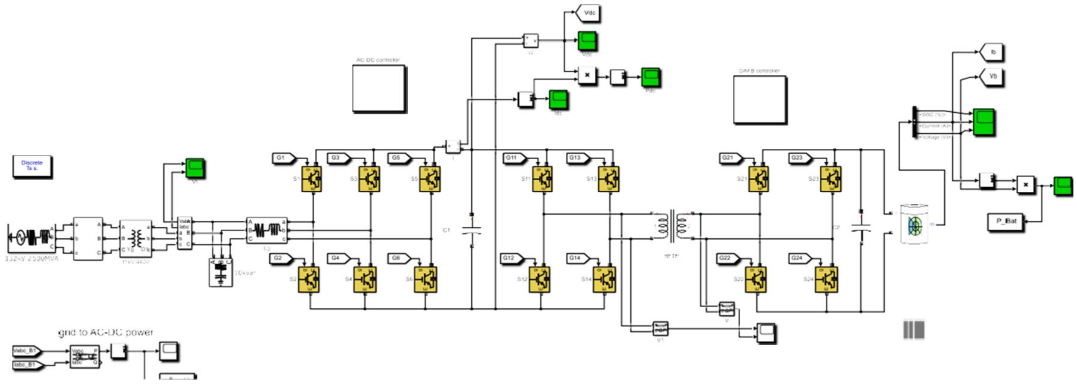

Figure 2: MATLAB Simulink model of the converter

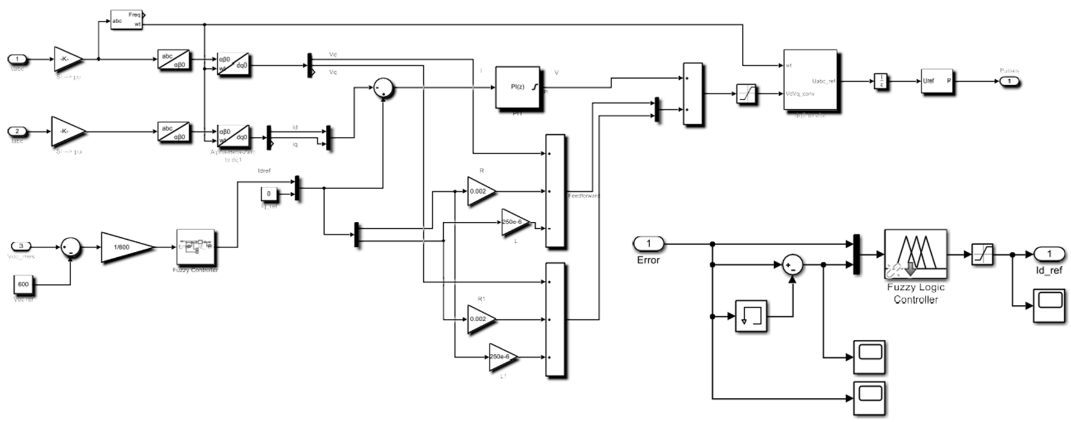

Figure 3: DC link Controller with Neuro Fuzzy controller

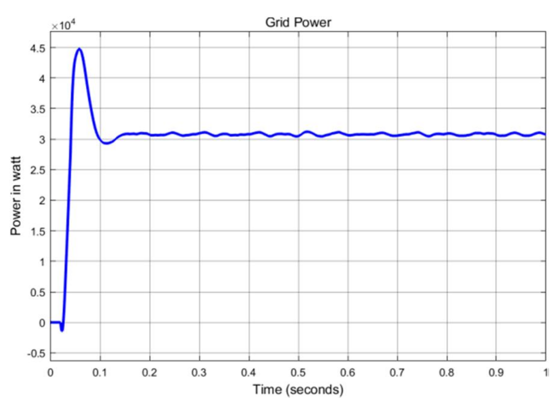

Figure 4 (a): Grid power in (G to V)

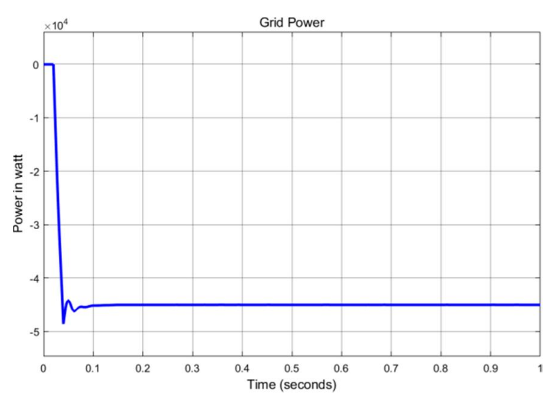

Figure 4 (b): Grid power in (V to G)

The MATLAB simulation results of dual active bridge converter with PI controller are shown in figures 4(a) to 6(b). The figure 5 (a) shows power taken from the grid during battery charging while figure 4 (b) shows power supplied to the grid from battery during discharging mode. The charging and discharging voltage and

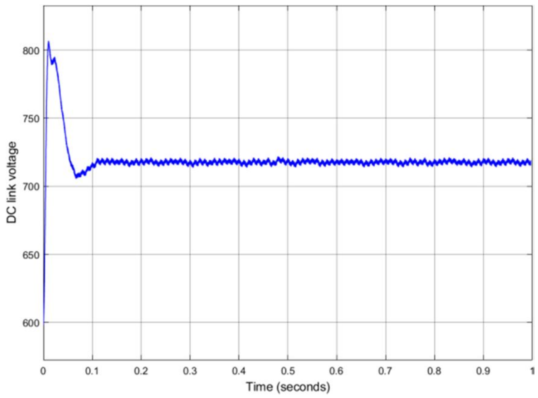

Figure 5 (a): DC link voltage (G to V)

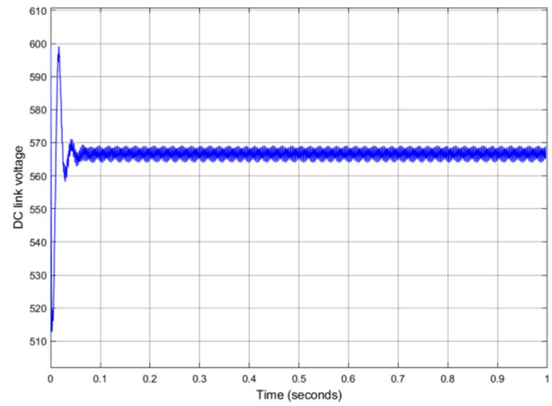

Figure 5 (b): DC link voltage (V to G)

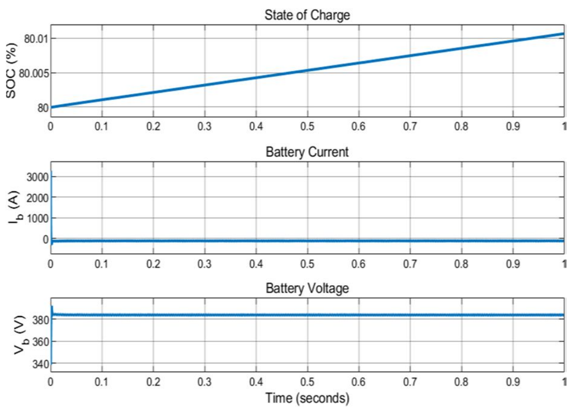

Figure 6 (a): Battery parameters (G to V)

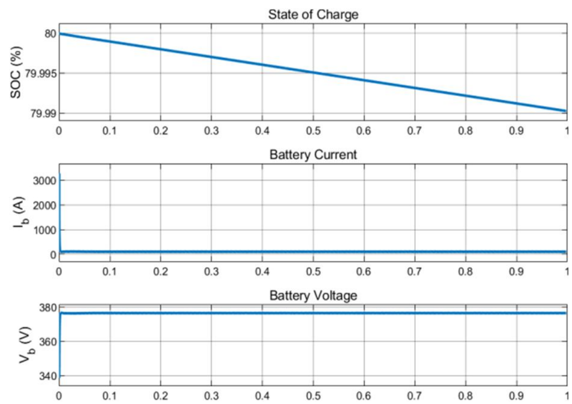

Figure 6 (b): Battery parameters (V to G)

state of charge are indicated in figures 5(a & b) and figure 6(a & b) respectively. The MATLAB simulation results of dual active bridge converter with Neuro Fuzzy controller are shown in figures 7 (a) to 9 (b). The neuro fuzzy controller for this simulation is first trained with the data of fuzzy logic controlled DAB converter for 3000 data points. In case of the Neuro fuzzy controller, it is seen that the transient characteristics of the converter are improved. The overshoots are reduced as compared to PI controller.

IV. Conclusion

By comparing the results of figure 4 (a) & figure 7(a), and figure 4 (a) & 7 (a), it is clearly seen that theovershoot in the value of power and DC link voltage is reduced with neuro fuzzy controller. Also the ripple contents of the DC link voltage and slightly less in case of Neuro Fuzzy controller. Thus it can be concluded that the transient characteristics of dual active bridge converter can be improved by implementation of the neuro fuzzy controller. The training of the neuro fuzzy controller is key for effectiveness of the controller.

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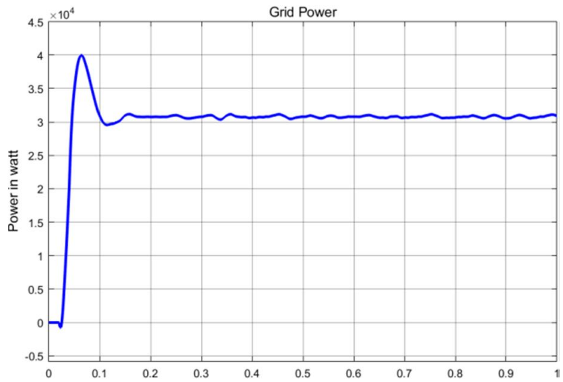

Figure 7 (a): Grid Power (G to V)

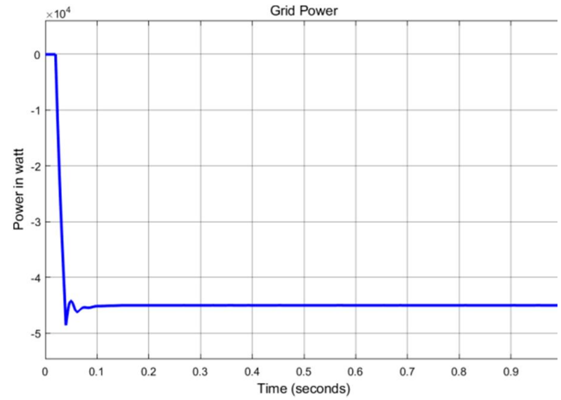

Figure 7 (b): Grid Power (V to G)

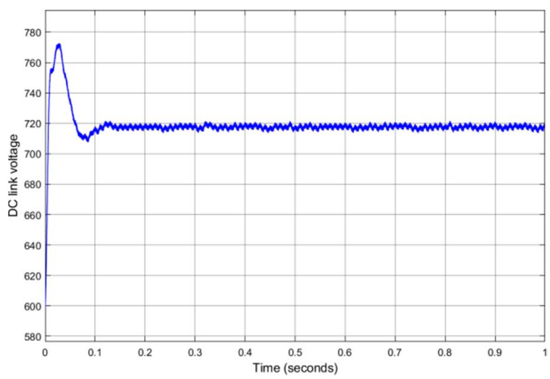

Figure 8 (a): DC link voltage (G to V)

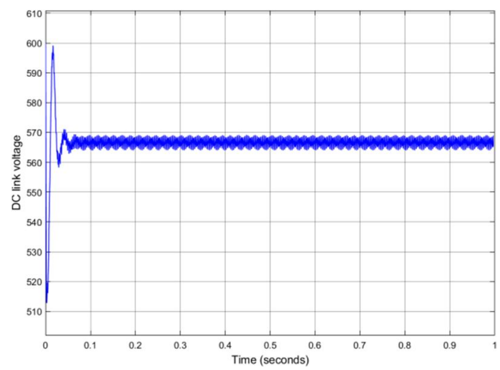

Figure 8 (b): DC link voltage (V to G)

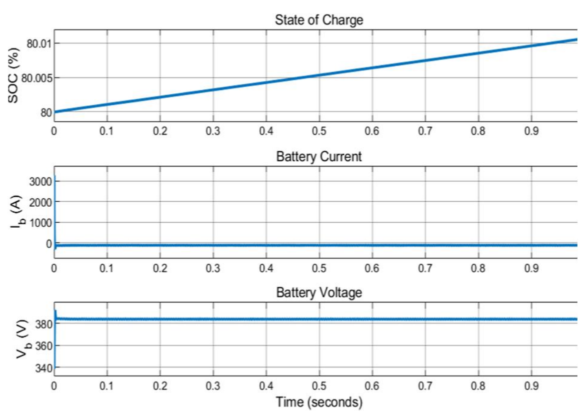

Figure 9 (a): Battery Parameters (G to V)

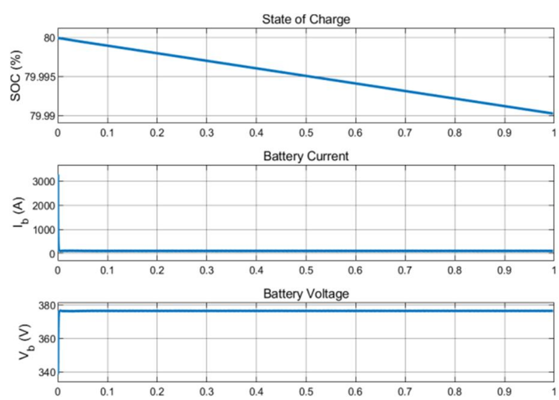

Figure 9 (b): Battery Parameters (V to G)

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